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COMPARATIVE EFFECTS OF CERTAIN SULPHUR FUNGICIDES ON McINTOSH APPLE TREES

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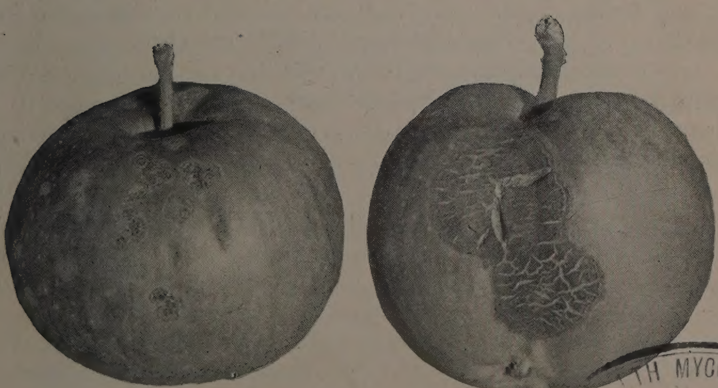

Scab is the chief reason for applying fungicides to apple trees in Maine.

CONTENTS

BULLETIN 464

COMPARATIVE EFFECTS OF CERTAIN SULPHUR FUNGICIDES ON McINTOSH APPLE TREES

Donald Folsom[1]

SUMMARY

Dry lime sulphur spray and elemental sulphur spray and dust were compared as to their effects on scab control, leaf burning, fruit quality, bloom, trunk growth, and fruit yield. This was done 1928-1943 inclusive with 335 McIntosh trees in 45 ten-tree plots. The 45 plots were assigned in equal numbers to 5 kinds of spray and dust treatments that were continuous on the same plots year after year. The 9 plots of each treatment series were scattered about the orchard to provide similar soil conditions for the 5 treatment series. These were similar also with respect to pruning, sod, mulching, fertilizing, and weather prevailing during any application of spray or dust materials. Winter injury in the wood was general. Fruit yield was not affected by the distribution of pollinator trees or by relative abundance of bloom.

Scab control with elemental sulphur spray was less effective on leaves, but more effective on fruits, than with lime sulphur spray, so that the final result in controlling fruit scab was about the same by the two methods. Scab was controlled well except when the dust was not used in sufficient amount, and in the check plots which were treated only with lead arsenate spray. Lead arsenate caused the most brown leaf burning, but this did not reduce fruit yield to a corresponding extent. Lime sulphur often russeted the fruits more than did elemental sulphur, but otherwise improved fruit color slightly.

Lime sulphur decreased the abundance of bloom and increased the early summer drop. The increased drop caused a decrease in yield, but the smaller number of fruits was compensated for in part by somewhat larger fruit. The increase in yield from using elemental sulphur instead of lime sulphur over a 10-year fruiting period was 32 per cent, or over 5 bushels per tree. The additional cost of the elemental sulphur for the 10 years was only about 5 cents per tree. When some trees were then shifted from elemental sulphur to lime sulphur, or *vice versa*, there was a delay of one year before the change affected bloom and fruit yield.

[1] Plant Pathologist.

Trees that grew faster yielded more, under the same fungicidal treatment, in the same soil type, or with elevation and type of nursery stock the same. The trees with the larger trunk girth at the end of a 12-year period had a significantly higher total fruit yield over the period. The size of the trunk girth of trees at the time of setting gave some indication of the size of trunk girth after 12 years in the orchard, and gave considerable indication of the total fruit yield for the entire period.

Trunk growth was not affected by fungicidal treatment. Consequently after using lime sulphur for a number of years, maximum fruit yield was obtained within one year after shifting to a less injurious fungicide.

Trees grew faster during the "off years" of bearing than during the years of heavy fruit yields.

In some cases fruit yield was reduced by shallower hardpan or by more sand and gravel in the soil. Elemental sulphur, especially in dust form, increased soil acidity somewhat but without affecting trunk girth or fruit yield. The effect of soil variation and of elevation was negligible in comparing the several treatment series, due to the number of plots and their distribution.

When one year was compared with another, a wetter May resulted in a longer interval between prepink and calyx dates. Also, the earlier the prepink date, the longer was the prepink-calyx interval. With a longer prepink-calyx interval there was more leaf scab and a greater lime sulphur fruit drop. At the same time, in general the "on year" and "off year" fluctuations in fruit yield in the lime sulphur trees corresponded with those in the elemental sulphur trees.

With the methods of application used, scab was controlled effectively with about 21 gallons of spray mixture per tree per season (about 3 gallons per application) even when the trees had reached their 17th year in the orchard and an annual yield rate of 7 bushels per tree.

A growing season that starts earlier, judging from the prepink date, generally has earlier pink and calyx dates but also has longer intervals between these dates. Thus records can be used to make a table for forecasting the later dates. This permits planning for the use of a midbloom application in years of probably long pink-calyx intervals, and for the use of more cover applications in years of earlier calyx dates.

A review of certain reports and reviews of the literature made by investigators in other states, indicate that certain comparative effects of sulphur fungicides are rather similar elsewhere to those found in Maine in this study.

INTRODUCTION

In 1928, apparently few if any experiments had been set up to measure the alleged injurious effects, on apple trees, of lime sulphur in comparison with elemental sulphur. Consequently the opportunity was taken of dividing a new McIntosh orchard into 45 ten-tree plots which would be subjected to several kinds of fungicidal treatments, each treatment being applied to the same plots year after year. Many of the detailed results have been reported previously in progress reports (*3, 4*)[2] but certain general conclusions seem worth presenting, now that the experiment has been concluded after 16 years.

GENERAL COURSE AND CULTURAL CONDITIONS OF THE EXPERIMENT

The orchard was established on Highmoor Farm in southwestern Maine, on a gradual west slope where a Ben Davis apple orchard had grown for about 42 years followed by a brief intermission of use for annual crops. When the 45 plots were laid out on a map in 1928, 5 sets of 9 plots each were chosen so as to have similar ranges of surface-soil conditions and similar distributions in the orchard. Then these 5 sets of plots were allotted by chance to 5 kinds of continuous spray and dust treatments.

Red Delicious and Cortland pollinator trees were well-spaced and at a ratio of 1 of them to 20 McIntosh. It may be stated now that greater proximity of the McIntosh trees to the pollinator trees resulted in no increase in McIntosh yield rate. Further, the McIntosh trees always set more fruit than they could hold through June and early July.

Pruning, kept to the minimum needed for the leader system of scaffold branches, and the application of nitrogenous fertilizer were completed each year uniformly for all trees before the plot stakes were put in position. A sod was needed to support the sprayer in wet spring weather. The trees were mulched alike using the grass mowed from the sod. The trees were set 20 feet apart in the row with the rows about 35 feet apart. Some trees died or were removed the first two years but were replaced immediately so that competition was similar for the 335 McIntosh "count trees"—those in place through the whole period of the test and used for analysis of data. Fruit bearing began in 1934. The tallest trees were 17 to 20 feet high by the end of 1943. Chronic winter injury to the wood, characteristic of Maine McIntosh when not grafted onto hardy interstocks, was found in all sample trees tested by borings,

[2] Italic numbers in parentheses refer to Literature Cited.

and in the alternate trees removed for thinning in the fall of 1943. (Oral communication from Dr. M. T. Hilborn.)

The 5 kinds of continuous spray and dust treatments were as follows: A, dry lime sulphur spray; B, elemental sulphur spray (for types see footnote in Table 1); C, elemental sulphur dust (bentonite type); D, lead arsenate spray just sufficient to control certain severely injurious leaf-eating insects such as the eastern tent caterpillar, *Malacosoma americanum* (F.), the gypsy moth, *Porthetria dispar* (L.), and the fall webworm, *Hyphantris cunea* (Drury); E, lead arsenate for all insects as in the standard Maine schedule, through 1935, and dry lime sulphur spray in subsequent years. The only disease present was the one that was primarily the subject of the experimental study, that is, scab caused by the fungus *Venturia inaequalis* (Cke.) Aderh. As it turned out, the A plots behaved like the E plots and the B plots behaved like the C plots, giving 18 plots for the study of lime sulphur and 18 plots for the study of elemental sulphur. The D plots served as checks except for such control of scab as the lead arsenate effected. Lead arsenate was added to A, B, C, and E according to the standard Maine schedule.

Through 1940, spray was applied with single-nozzle guns from the ground, one tree, one plot, and one kind of treatment at a time, and dust was applied with a tractor-drawn power duster. In 1941, 1942, and 1943, spraying was applied with an 8-nozzle broom from a seat on top of the tank, one row at a time and one kind of treatment at a time. In this 3-year period each plot was split; 5 trees in one row received lime sulphur spray and the 5 trees in the other row received elemental sulphur spray. Thus 20 per cent of the trees continued to receive lime sulphur, 20 per cent were shifted from lime sulphur to elemental sulphur, 20 per cent continued to receive elemental sulphur, 20 per cent were shifted from elemental sulphur to lime sulphur, and the other 20 per cent were shifted from check lead arsenate to either lime sulphur or elemental sulphur.

With few exceptions, each scheduled application was made with all materials on the same day, beginning with dust at sunrise, with no intervening rain. Usually 7 applications were made during the growing season—prepink, pink, calyx, and 4 cover. (See footnote in Table 9 for definitions of the tree stages, prepink, pink, and calyx.)

Measurements were made each year on each tree for abundance of bloom, yield, and final trunk circumference. Well-distributed blindly picked sample shoots were examined for percentage of leaves scabby and "burned." Random bushel samples of fruit were examined for scab, russeting, fruit size, and color.

COMPARISON OF LIME SULPHUR, ELEMENTAL SULPHUR, AND LEAD ARSENATE

SCAB CONTROL

Scab was controlled well enough where sulphur fungicides were used so that the disease probably had little effect upon yield rate and growth. The trees sprayed with lime sulphur 1929-1943 inclusive are compared in Tables 1 and 2 with the trees sprayed with elemental sulphur. The former trees had about half as many leaves scabby but about the same proportion of fruits scabby. Under the same treatment a positive significant correlation was found between percentage of leaves scabby and percentage of fruits scabby in a study made in 1942. Therefore, with more leaves scabby under elemental sulphur, one might well expect still more fruits scabby, in comparison with lime sulphur trees. The fact that, with more leaves infected under elemental sulphur, there was the same percentage of fruits infected, indicates a compensating better protection of the fruits by this material than by lime sulphur.

During the period 1929-1940 inclusive when sulphur dust was used, with this material 6.2 per cent of the leaves were scabby *vs.* 7.8, 3.7, and 27.1 per cent respectively for elemental sulphur spray, lime sulphur spray, and minimum lead arsenate spray (checks). During the period 1934-1940 inclusive the average annual percentage of fruits scabby for these four treatments was respectively 5.4, 1.4, 0.9, and 50.1.

LEAF BURNING

Brown leaf burning in the 7 years 1929-1935 was more prevalent under the full schedule of lead arsenate than under the lime sulphur and lead arsenate combination spray, 36 and 27 per cent respectively of the leaves being affected. However, the yield rate under the lead arsenate was much greater in this period than under lime sulphur (Fig. 2, E and A), showing that such leaf burning was not a determining factor in yield reduction.

FRUIT QUALITY

Lime sulphur, in comparison with elemental sulphur spray, often russeted the fruits more (Table 1). It also increased the size of the fruits when reducing the yield per tree. Fruit color was better on larger fruits. Altogether, with the russeting tending to offset the larger size and improved color under lime sulphur, the quality of the fruit seemed to be about the same under these two treatments.

TABLE 1

Lime Sulphur Spray vs. Elemental Sulphur Spray over Fifteen-Year Period 1929-43

Year		Kind of season	Kind of elemental sulphur sprays[1]	Leaves scabby		Fruits scabby		Fruits russeted		Trunk growth[3]		Blossom abundance[4]		Fruit yield per tree		Fruit size[5]		Fruit color[6]		Fruits clean[7]		Scab on checks	
A.D.	For orchard			LS[2]	ES[1]	LS	ES	LS	ES	LS	ES	LS	ES	LS	ES	LS	ES	LS	ES	LS	ES	Leaves scabby	Fruits scabby
				%	%	%	%	%	%	mm cm	mm cm			lbs.	lbs.					%	%	%	%
1929	2d		Fl.	2	7	—	—	—	—	2.8	3.0	—	—	—	—	—	—	—	—	—	—	35	—
1930	3d	Early	Fl.	2	7	—	—	—	—	6.1	6.0	—	—	—	—	—	—	—	—	—	—	29	—
1931	4th	Medium	Kol.	11	20	—	—	—	—	10.2	10.8	—	—	—	—	—	—	—	—	—	—	41	—
1932	5th	Medium	Kol.	2	3	—	—	—	—	9.6	10.6	—	—	—	—	—	—	—	—	—	—	19	—
1933	6th	Medium	Kol.	5	14	—	—	—	—	2.9	3.0	—	—	—	—	—	—	—	—	—	—	30	—
1934	7th	Medium	Fl.	0	0	0	0	1	1	3.2	3.3	17	54	T[8]	1	—	—	—	—	99	99	4	25
1935	8th	Late	Fl.	2	2	T	T	4	T	3.5	3.7	40	56	5	12	—	—	—	—	96	100	23	68
1936	9th	Medium	Fl.	8	14	2	3	T	0	4.4	4.2	66	73	7	9	—	—	—	—	98	97	25	33
1937	10th	Medium	Fl.	5	11	2	4	5	2	4.7	5.1	2.6	2.6	25	41	—	—	—	—	94	94	28	74
1938	11th	Early	Mic.	3	6	T	0	10	4	4.3	4.2	4.1	4.7	11	43	—	—	—	—	90	96	41	68
1939	12th	Late	Mic.	T	2	T	T	2	1	4.0	4.0	2.5	3.3	49	81	—	—	—	—	98	99	18	45
1940	13th	Late	Mic.	3	7	2	2	4	1	3.2	3.3	2.1	2.7	70	131	171	190	—	—	94	97	33	94
1941	14th	Early	Mic.	T	1	T	0	1	T	4.2	4.1	2.3	3.1	64	98	147	160	70	75	99	100	—	—
1942	15th	Early	Fl.	4	13	2	3	0	T	4.9	4.4	3.4	3.7	147	235	142	152	78	74	98	97	—	—
1943	16th	Late	Fl.	5	6	4	3	T	T	3.1	3.0	4.3	4.1	346	317	189	174	84	77	95	97	—	—

1 Flotation sulphur, Koloform, or Micronized sulphur, at 5 lbs. sulphur in 50 gal.
2 Dry lime sulphur at 4 lbs. in 50 gal.
3 In diameter by mm to 1932 inclusive, thereafter in circumference by cm., at height of 0.5 m.
4 To 1936, inclusive, by percentage of trees blossoming; thereafter, estimated in six grades from 0 (none) to 5 (most).
5 Number per 44-lb. bushel.
6 Percentage of surface red, as estimated.
7 Total fruits examined were about 60,000.
8 T means a trace, or less than 0.5 per cent.

TABLE 2

Lime Sulphur Spray vs. Elemental Sulphur Spray 1929-1943 According to Student's Method[1]

Period	No. of years	Characteristic	Means		Odds[2]
			Lime sulphur	Elemental sulphur	
1934-43	10	Leaves scabby, percentage	3.08	6.10	163:1
1934-43	10	Fruits scabby, percentage	1.31	1.53	7:1
1934-43	10	Fruits russeted, percentage	2.74	0.97	100:1
1929-43	15	Trunk growth, cm, circumference	3.43	3.45	2:1
1937-43	7	Blossom abundance	3.04	3.46	55:1
1935-43	9	Fruit yield, percentage basis	100.0	186.7	108:1
1934-43	10	Fruits clean, percentage	95.0	97.5	37:1

[1] Method as given in 9 using data in Table 1 of this bulletin.
[2] Significant only if over 30:1.

BLOOM IN RELATION TO FRUIT YIELD

Lime sulphur decreased the abundance of bloom significantly (Tables 1 and 2). However, blossoms were always in considerable excess over the number of fruits reaching maturity. Also, with the lower yield rate under lime sulphur the fruit size was larger. It seems that fruit yield was not affected by differences in bloom but was reduced by lime sulphur through an early summer drop which was followed by somewhat better sizing of the fruit.

TRUNK GROWTH AND FRUIT YIELD

Trunk growth of the 5 treatment series for 1929-1940 inclusive is shown in Fig. 1, yield each year in Fig. 2, and cumulative yield in Fig. 3. The kind of treatment had practically no effect upon trunk girth. The yield rate after the first 4 years of light bearing was considerably greater

TABLE 3

Current-Season and Accumulated Effects of Fungicides on Apple Tree Growth and Yield Rate 1940

Plot series	Treatment	No. of trees	Trunk girth attained		Fruit yield per tree			
					1940		1934-1940	
			cm.	Ratio[1]	lbs.	Ratio[1]	lbs.	Ratio[1]
A	Dry lime sulphur spray	66	42.8±0.5	100.0	70±4	100	167±11	100
B	Elemental sulphur spray	65	44.0±0.5	102.8	131±5	187	316±16	189
C	Elemental sulphur dust	65	41.8±0.7	97.7	107±6	153	300±19	180
D	Minimum lead arsenate spray	74	42.6±0.6	99.5	60±3	86	216±12	129
E	Full lead arsenate 1929-35, dry lime sulphur spray 1936-1940	65	43.4±0.7	101.4	67±5	96	174±15	104

[1] Based on first item taken as 100.0 per cent.

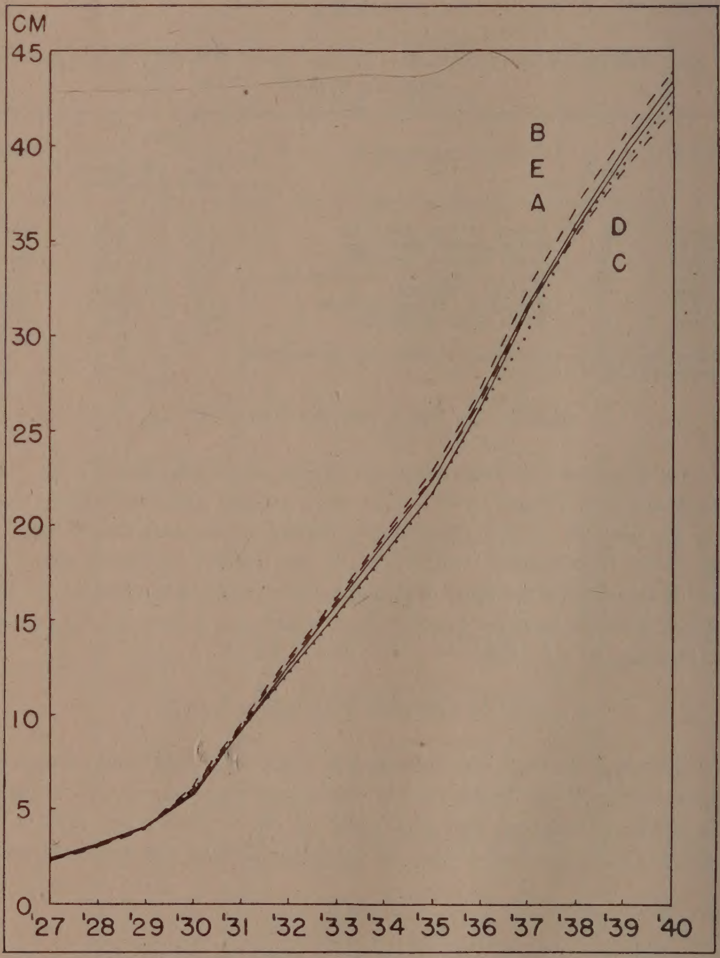

FIGURE 1. Average trunk growth per tree for 5 treatment series. In the order of rank in 1940: B, elemental sulphur spray; E, lead arsenate through 1935, then dry lime sulphur spray; A, dry lime sulphur spray; D, lead arsenate; and C, elemental sulphur dust.

each year under elemental sulphur spray or dust than under lime sulphur spray. From this it follows that the cumulative yield rate, also, was considerably greater under elemental sulphur spray or dust than under lime sulphur spray. The cumulative yield rate under the minimum lead arsenate treatment, was about midway probably because the scab present depressed the yield rate somewhat but not as much as did lime sulphur.

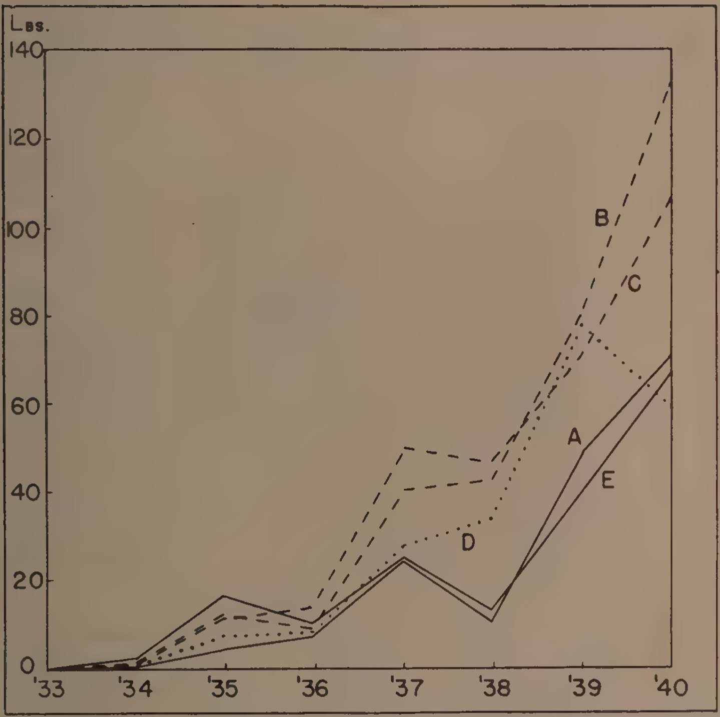

Figure 2. Average annual fruit yield per tree for 5 treatment series. In the order of rank in 1940: B, elemental sulphur spray; C, elemental sulphur dust; A, dry lime sulphur spray; E, lead arsenate through 1935, then dry lime sulphur spray; D, lead arsenate.

The data from the 335 count trees are used in Table 3 to show the effects of the 5 treatments on trunk girth attained by the end of 1940 and on yield rate in 1940 and during 1933-1940 inclusive. The spread in trunk girth is only 5.1 per cent and is not significant. Under elemental sulphur spray or dust, the yield rate either in 1940 or during 1934-1940 inclusive is significantly greater than under lime sulphur or minimum lead arsenate spray.

Data from pairs of trees only 20-35 feet apart, with each pair including two treatments, were analyzed with Student's method with the results summarized in Table 4. Generally the yield rate for 1934-1940 inclusive was significantly greater under elemental sulphur dust or spray than under lime sulphur or lead arsenate, and under lead arsenate than under lime sulphur.

When the 45 plots were split in 1941, disregarding those that had

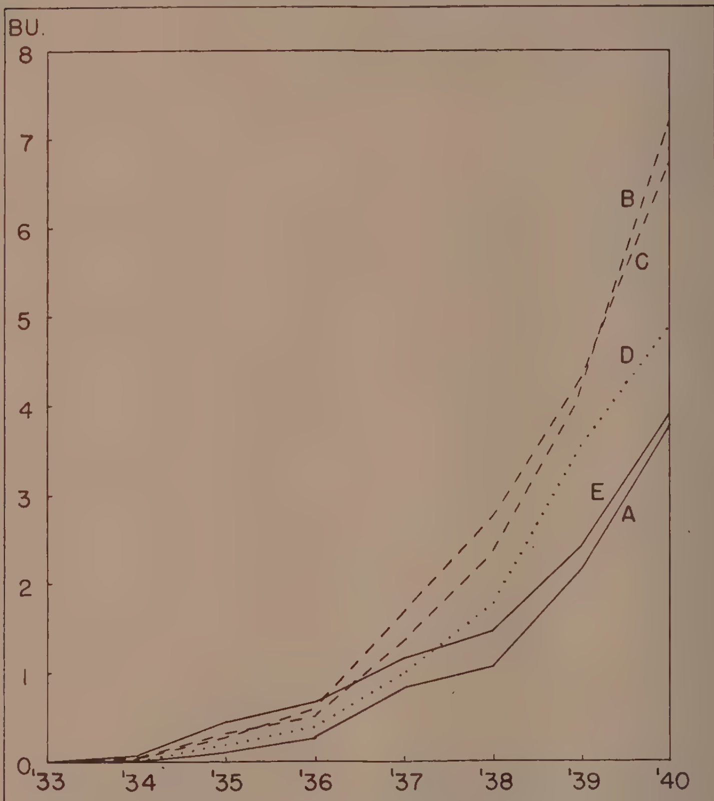

FIGURE 3. Cumulative annual fruit yield per tree for 5 treatment series. In the order of rank in 1940: B, elemental sulphur spray; C, elemental sulphur dust; D, lead arsenate; E, lead arsenate through 1935, then dry lime sulphur spray; A, dry lime sulphur spray.

been in set D, there were 72 half plots of 4 types. Sets F and G had received dry lime sulphur spray (in series A and E) through 1940 and were to receive respectively lime sulphur and elemental sulphur spray 1941-1943. Sets H and I had received elemental sulphur spray or dust (in series B and C) through 1940 and were to receive respectively lime sulphur and elemental sulphur spray 1941-1943. If the divergence in yield rate between series A and E on the one hand, and series B and C on the other, in 1934-1940 were due to treatment, series G should rise above F, and series H should fall below I, in 1941 and following years. The results are given in Fig. 4 as averages of the trees in each series.

TABLE 4

Yield Rate 1934-1940 Inclusive for Treatments Compared According to Student's Methods[1]

Treatments[2]	Lbs. per tree[3]	Pairs of trees	Odds[4]
A, B	268, 366	11	9.1:1
A, C	104, 258	14	80:1
A, D	148, 272	16	1428:1
A, E	145, 140	18	1.92:1
B, C	264, 269	10	1.59:1
B, D	378, 176	16	480:1
B, E	302, 101	12	55:1
C, D	296, 209	16	11.5:1
C, E	356, 155	23	8000:1
D, E	217, 197	14	2.0:1
A & E, B & C	153, 324	60	4999:1
A & E, D	171, 246	30	171:1
B & C, D	337, 193	32	750:1

[1] Method as given in *9*.
[2] For characterization see Table 3.
[3] For the paired treatments, respectively, in the first column.
[4] Significant only if over 30:1.

Not much change occurred in 1941. In 1942 the expected reaction occurred, the yield rate of G rising to that of I and the yield rate of H falling to about that of F. The results were interpreted to mean that a cumulative effect of elemental sulphur through 1940 (or the effect in 1940) had delayed the deleterious effect of lime sulphur for a year, and that a cumulative effect of lime sulphur (or the effect in 1940) had delayed the comparatively beneficial effect of elemental sulphur for a year. This idea is supported by the fact (see Table 1) that abundance of bloom remained low for lime-sulphur trees in 1941.

In 1943 all series yielded about the same and yielded more than in any previous year. By this time the branches of adjacent trees in the same row were interlacing in many instances, fruit drop just before harvest time was excessive, and it seems probable that competition between trees in a year favorable to high yield reduced the capacity of many of them to benefit from elemental sulphur. At any rate, after 9 successive years in which the yield rate was greater with elemental sulphur than with lime sulphur, the tenth year broke the trend. The matter was not followed further due to the use of the trees in 1944 for a test of organic fungicides and to the removal of alternate trees in each row in 1945.

The improvement in yield rate under lime sulphur in 1943 was correlated with a change in fruit size. In the 3 previous years, with the lower yield rate the fruit size was larger for the lime sulphur trees than for the elemental sulphur trees, indicating that lime sulphur reduced the yield rate through an early reduction in the number of fruits, this reduction being made up in part, before the growing season was over, by greater fruit size. In 1943 apparently lime sulphur did not reduce the

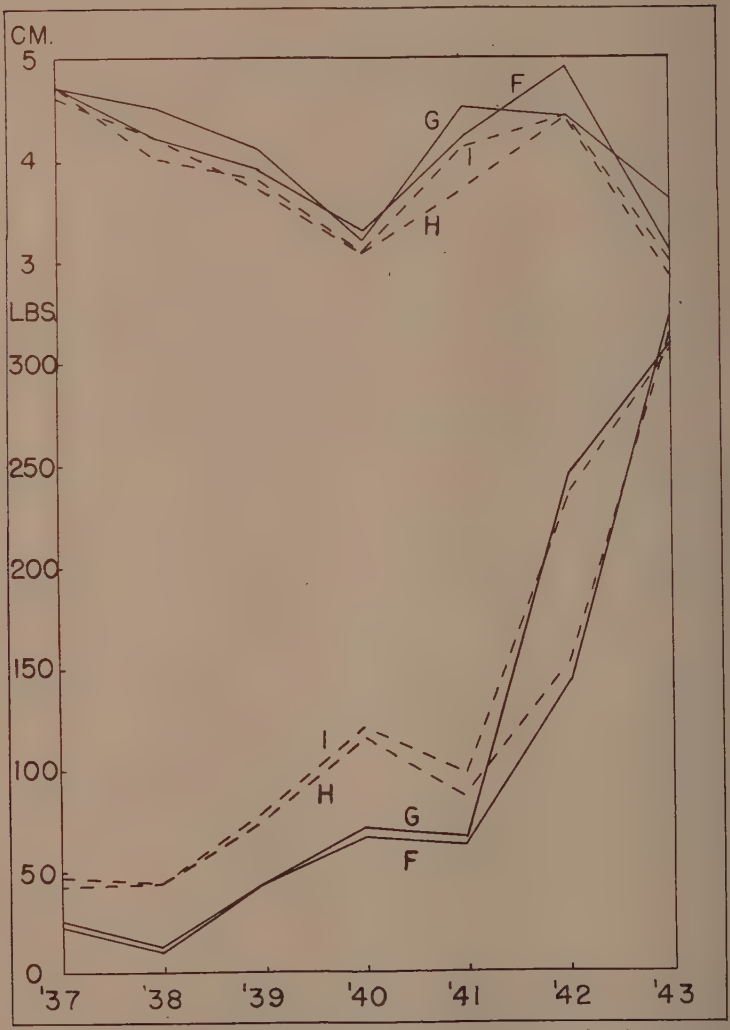

FIGURE 4. Below, average annual fruit yield per tree for 4 treatment series: F, dry lime sulphur spray; G, dry lime sulphur spray through 1940, then elemental sulphur spray; H, elemental sulphur spray through 1940, then dry lime sulphur spray; I, elemental sulphur spray. Above, average annual increase in trunk girth per tree for the same 4 treatment series represented below.

number of fruits; in fact, a 9 per cent greater yield per tree and a 9 per cent greater number of fruits per volume bushel (see Table 1) showed

that considerably more fruits had been kept by the trees under lime sulphur. How much this unusual result with lime sulphur was due to some peculiarity of the season and how much to the lower 1942 yield in trees now too close together, is an unanswered question. It is of interest that the lime sulphur trees dropped down again in yield rate in 1944 when treated with Fermate, although the leaves looked as vigorous as on the elemental sulphur trees (treatments G and I continued) (*5*). This drop probably was an effect of the high 1943 yield under lime sulphur rather than an effect of the use of Fermate in 1944.

Trees under treatment I (elemental sulphur through 1943) grew to an average trunk girth of 54.2 cm. and under treatment F (lime sulphur through 1943) to 55.2 cm., a nonsignificant difference of about 2 per cent. The respective yield rates through 1943 were 731 ± 35 lbs. and 965 ± 40 lbs., with a significant difference which amounted to a 32 per cent increase for elemental sulphur. In practical terms, this was an accumulated difference of over 5 bushels per tree, at a cost of only about 1 cent per additional bushel so far as fungicides were concerned.

WOOD FORMATION IN RELATION TO FUNGICIDES AND FRUIT PRODUCTION

It has been shown that a fungicidal difference which reduced fruit production considerably did not reduce trunk growth more than a trifle if any. This is important because, under each treatment, there was a high positive correlation between trunk girth and yielding capacity (Table 5), and therefore a yield-depressing fungicide like lime sulphur can be used for any number of years on a set of trees and yet upon

TABLE 5

Correlation Between Trunk Circumference and Yield Rate Within the Same Treatment Series

Treatment[1]	No. of trees	Characters correlated	r[2]
A	67	Trunk circumference and yield 1938	+0.548
B	66	Do	+0.644
C	65	Do	+0.715
D	74	Do	+0.293
E	68	Do	+0.548
		Trunk circumference and yield	
A	67	through 1938	+0.621
B	66	Do	+0.603
C	65	Do	+0.714
D	74	Do	+0.537
E	68	Do	+0.561

[1] For characterization see Table 3.
[2] Highly significant in each instance except the +0.293, which is significant (*12*, Table 7.3).

changing to a benign fungicide like elemental sulphur the trees will be as large and as capable of yielding well, at least in a year, as if they had always received the elemental-sulphur fungicide.

At the same time, an increase in yield rate from one year to the next was usually accompanied by a decrease in wood formation as measured by trunk girth increase, and *vice versa* (Fig. 4). It seems therefore that the decrease in fruit yield by lime sulphur might have tended to increase wood formation, but any effect in this direction was apparently reduced

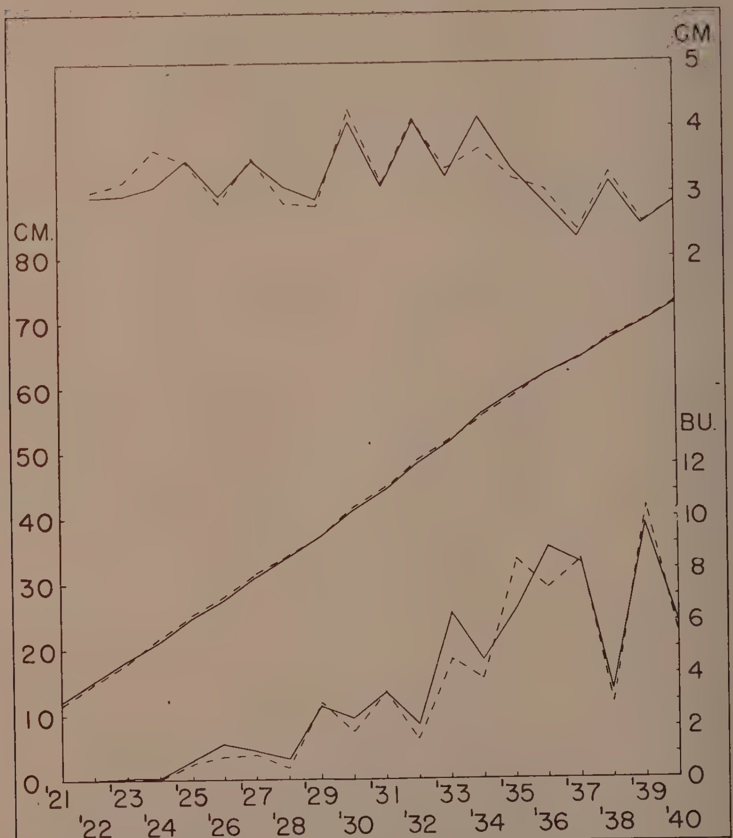

FIGURE 5. Averages per tree each year in two adjacent rows. Above, increase in trunk girth; middle, trunk girth; below, fruit yield. The two rows were treated alike except 1935-38 inclusive, when the row represented by the broken line received half-strength lime sulphur spray *vs.* full strength for the other row.

enough through leaf injury so that no more trunk growth occurred than under elemental sulphur.

The data from an older orchard (Fig. 5) show again how McIntosh trees can maintain a rather regular rate of trunk growth year after year, with a correspondingly greater yielding capacity, but with a year-to-year fluctuation in yield rate and an opposite fluctuation in wood formation. These trees were in two rows about 35 feet apart, and in the 4 years 1935 to 1938 one row (north, represented by broken lines in the figure) received half-strength (2-50) dry lime sulphur spray while the other received full-strength (4-50). The reduction in strength apparently increased the yield in 1935, but this was followed by a decrease in 1936 while in succeeding years there was no effect on yield, and growth rate was modified little or none at any time.

The decrease in total carbohydrate production by lime sulphur, in comparison with elemental sulphur, can be approximated on the basis of certain figures (specific gravity of the wood, 0.70; percentage of wood consisting of carbohydrates, 92; percentage of fruit consisting of carbohydrates, 11) and on the assumption that the total wood is equal to that of a cylinder as high as the tree and as thick as the trunk where measured. Then the 1942 increase in wood carbohydrates was about 26 pounds per tree under each treatment, and the 1942 production of fruit carbohydrates was about 17 pounds under lime sulphur and about 26 pounds under elemental sulphur. Thus under lime sulphur there was a reduction of 35 per cent in fruit carbohydrates but only 17 per cent in both fruit and wood carbohydrates combined. Or, under elemental sulphur in comparison with lime sulphur there was an increase of 53 per cent in fruit carbohydrates but only 21 per cent in both fruit and wood carbohydrates combined.

Soil Acidity

Soil acidity was studied for 48 pairs of trees. The two trees of each pair were alike as to fungicidal treatment through 1940 but different 1941-1943. On the assumption that elemental sulphur might lower the pH and thus lower yield, the 48 pairs were also selected as being those with the greatest difference between the two trees in both girth and yield, or in yield, in favor of lime-sulphur over elemental sulphur spray 1941-1943. The data (Table 6) show a slight drop in pH (*i.e.,* slightly greater acidity) with the use of elemental sulphur spray through 1940 and still more of a drop with the use of sulphur dust through 1940. Reduction of orchard soil pH by sulphur sprays or dusts has also been reported in New Jersey (*2*, p. 14-15). Correlation between yield and pH in the several treatment groups of trees is not consistent. Also, the highest posi-

TABLE 6

Soil pH and Yield After Different Fungicidal Treatments

Pairs of adjacent trees[1]	Treatment through 1940	Treatment 1941-1943	Sulphur per acre 1937-1943	Yield per tree 1943	Average pH 1946[2]	Correlation between pH and yield
			lbs.	lbs.		r
5	Minimum lead arsenate	Lime sulphur	450	340	5.74	+0.772
		Elemental sulphur spray	780	182	5.59	+0.126
19	Lime sulphur	Lime sulphur	950	381	5.76	+0.450[3]
		Elemental sulphur spray	1280	266	5.60	+0.129
12	Elemental sulphur spray	Lime sulphur	1280	459	5.55	+0.347
		Elemental sulphur spray	1610	354	5.53	−0.882[4]
12	Sulphur dust	Lime sulphur	5450	440	5.25	−0.132
		Elemental sulphur spray	5780	337	5.31	−0.217

[1] Each pair alike as to fungicidal treatment through 1940, consisting of trees 20 to 35 feet apart, and selected from those pairs showing the greatest difference in both girth and yield, or in yield, in favor of the tree receiving lime sulphur 1941-1943.
[2] The pH of the samples was determined by Paul N. Carpenter, Assistant Agronomist. The pH of the predominant "fine sandy loam" in this orchard in 1928 was 5.8 to 5.5 as determined by D. B. Lovejoy and J. A. Chucka, then soils specialists of this Station.
[3] Significant (*12*, Table 7.3).
[4] Highly significant (*12*, Table 7.3).

tive correlation is at a high pH while all negative correlation is at a low pH, where there should be a positive correlation if soil acidity had any effect. It may be concluded that elemental sulphur, especially in dust form, increased soil acidity but that the increase had no proved effect upon girth or yield.

EFFECT OF VARIABLES OTHER THAN FUNGICIDAL TREATMENT

SOIL TYPE

Harris pointed out in 1920 (*8*) that no field is uniform in capacity for crop production. As indicated previously in this bulletin and in a previous one (*4*), surface characteristics of the soil, mostly a "fine sandy loam," were taken into account in the division of the 45 plots into 5 treatment series. A detailed soil map was made by soil specialists (K. V. Goodman and D. S. Fink) in the fall of 1939. About 58 per cent of the trees were found to be growing in Charlton, 39 in Sutton, 1 in Whitman, and 2 in outwash, the Charlton and Sutton types being essentially the same originally but modified by differences in drainage (*13*, p. 1031-1032). The trunk girth and cumulative yield through 1939 were studied in relation to the various soil types and subtypes, and it was determined that correction for soil effect would change the average of a treatment series no more than about 1 per cent in girth and only from 2 to 4 per

cent in cumulative yield rate, in any one case. In addition, the correction, if made, would have merely increased the difference already found in favor of elemental sulphur in comparison with lime sulphur.

STOCK TYPE AND ELEVATION

As indicated previously (*4*, p. 453), upon planting from the upper to the lower elevations of this orchard there was a shifting from one kind of nursery stock to another. A study similar to that on soil types showed that differences in both elevation and stock type together had been without effect upon trunk growth of the several treatment series as a whole and that cumulative yield would need correction by only 2 per cent.

SUBSOIL

Further study showed that there were some striking differences between some trees originally of the same stock and of the same size, grown in the same soil under the same treatment, and only 20 to 35 feet apart. After the conclusion of the study, borings were made in the soil to see if differences in growth and cumulative yield could be attributed to subsurface differences. There was, as elsewhere, a highly significant correlation between girth and cumulative yield, but there was no significant correlation between girth or yield and depth of apparently better colored subsoil. However, shallower hardpan or more sand or gravel usually was associated with less girth and yield.

WEATHER AND RAPIDITY OF DEVELOPMENT OF FOLIAGE AND BLOOM

Meteorological records taken at Highmoor Farm 1939-1945 inclusive and at Lewiston, 13 miles distant, 1931-1938 inclusive, were used to learn May precipitation, precipitation per day during the interval prepink to calyx, days with over a trace of precipitation in May, and percentage of days with precipitation in the interval prepink to calyx. These all showed positive correlation ($r = +.414$ to $+.507$) with the length of the interval prepink to calyx. This is not surprising, since always most of this interval was in May and usually rainy days in May are cool days which retard the development of apple foliage and bloom.

Correlations were studied between earliness of the prepink, pink, and calyx dates, intervals between these, leaf scab percentages, and ratio of lime sulphur tree yield to elemental sulphur tree yield, using records available for 1931-1944 inclusive. The results (Table 7) indicate the following relationships. The earlier the prepink, the earlier were the pink and calyx, and yet the longer was the interval between prepink and pink or calyx. The earlier the pink, the earlier was the calyx but also

TABLE 7

Correlations Between Blossom Stages, Scab, and Yields

	Days Prepink to Pink	Pink date	Days Prepink to Calyx	Days Pink to Calyx	Calyx date	Leaves scabby, per cent			Ratio l.s. yield/el. sul. yield
						Check	L. sul.	El. sul.	
Prepink date[1]	−.383	+.950[2]	−.682[2]	−.639[3]	+.839[2]	−.817[2]	−.662[2]	−.678[2]	+.238
Days Prepink to Pink						+.516	+.508	+.495	−.207
Pink date[1]				−.633[2]	+.905[2]	−.683[3]	−.538[3]	−.560[3]	+.171
Days Prepink to Calyx						+.803[2]	+.719[2]	+.674[2]	−.783[3]
Days Pink to Calyx						+.617[3]	+.567[3]	+.519	−.584
Calyx date[1]						−.628[3]	−.379	−.437	−.081
Check leaf scab per cent							+.924[2]	+.929[2]	−.622
L. sul. leaf scab per cent								+.982[2]	+.387
Elemental sul. leaf scab per cent									+.203

[1] Days after April 20, averaging May 8, May 16, and May 29 respectively for prepink, pink, and calyx applications 1931-1944 inclusive.
[2] Highly significant r (*12*, Table 7.3).
[3] Significant r (*12*, Table 7.3).

the longer was the interval between. The longer these intervals, which were also intervals between the applications of fungicides, the more leaf scab there was in the check trees, the lime sulphur trees, and the elemental sulphur trees, and the smaller was the ratio of lime sulphur tree yield to elemental sulphur tree yield. Evidently a longer prepink-calyx interval, sometimes due to wetter, cooler, and cloudier weather, favored leaf scab development and also increased fruit drop in the lime sulphur trees.

From the elemental sulphur tree yields of 1933-1944 inclusive, a moving 5-year average of the annual yield per tree was calculated. The percentage that the actual yield rate in each year 1935-1942 was of the moving 5-year average centered in that year, was determined. The lime sulphur tree yields of 1933-1943 inclusive were dealt with similarly. Between these annual percentages for the two treatments there was a significant positive correlation (r = +.763). However, the correlations between them and the various meteorological factors mentioned above were inconsistent and not significant. Apparently fluctuations in yield from year to year moved similarly for both elemental sulphur and lime sulphur trees, but without a meteorological explanation evident in the available records.

AMOUNT OF FUNGICIDE APPLIED

The amount of spray material or dust used was measured for each application. The data in Table 8 permit a comparison, year by year,

TABLE 8

Scab Control in Relation to Amount of Fungicide Applied

Gun nozzles	Year		Bu. per tree	Amount per tree per application			Leaves scabby				Fruits scabby			
	A.D.	Orchard		L.s.	El.s.	Dust	Ch. l.a.	L.s.	E.s.	Dust	Ch. l.a.	L.s.	E.s.	Dust
				gal.	gal.	lbs.	%	%	%	%	%	%	%	%
1	1937	10th	0.73	1.6	1.7	1.42	28	5	11	12	74	2	4	5
1	1938	11th	0.66	2.1	2.0[1]	1.33	41	3	6[1]	6	68	T[2]	0[1]	1
1	1939	12th	1.44	2.4	2.5	1.27	18	T	2	2	45	T	T	2
1	1940	13th	1.90	2.7	2.5	1.10	33	3	7	13	94	2	2	25
8	1941	14th	1.98	2.3	2.5			T	1			T	0	
8	1942	15th	4.09	2.5	2.7			4	13			2	3	
8	1943	16th	7.35	2.8	2.8			5	6			4	3	
8	1944	17th	5.4		3.0		39		12		89		2	
8[3]	1945	18th	1.00	3.2	3.0		88	41	55		100	90	98	

[1] Excess sulphur added by mistake in formula.
[2] Trace—less than 0.5 per cent.
[3] Adequate spraying equipment not available.

between the amount used per tree per application and other things such as age, yield rate, type of spray gun, and scab control. The 8-nozzle broom as used was more economical than the 1-nozzle gun as to labor and materials. Although coverage with the dust was apparently good, the amount used per tree decreased until in 1940 it did not control scab adequately. The coverage and scab control with spraying was good through 1944 (*5*), but the amount used did not increase in proportion to the age of the trees or their yield rate. In 1945, war conditions etc., made adequate spraying equipment unavailable and with about the same amount of spray material used as in previous years, the control of scab became very poor and the yield rate was decreased considerably (*6*).

FORECASTING FROM EARLY STAGES IN ANNUAL DEVELOPMENT OF FOLIAGE AND BLOOM

The dates of the standard stages of development of foliage and bloom were studied to see if they could be used for forecasting the time of the pink and calyx applications or the yield rate. The advantages of such forecasting are given below. The dates for 1931-45 inclusive were used to determine correlations which in turn were used to get these regression equations:

Date (days after April 20) of prepink $= x$, date of pink $= y$; $y = .930x + 9.2$
Date of prepink $= x$, date of calyx $= y$; $y = .633x + 27.8$
Date of pink $= x$, date of calyx $= y$; $y = .699x + 21.0$
Date of prepink $= x$, interval prepink to calyx $= y$; $y = -.363x + 27.7$
Date of pink $= x$, interval pink to calyx $= y$; $y = -.300x + 21.0$

These were put onto cross-section paper and the graphs used to forecast the dates and intervals given in Tables 9 and 10. The deviation of the actual dates and intervals from the forecasted dates and intervals were calculated and these also are given. In 80 per cent of the years, the deviation of the prepink to pink interval was no more than two days from the forecast based on the prepink date and the regression equation. In 67 per cent of the years, the calyx date was no more than two days

TABLE 9

Relation of Prepink Date to Later Development of Foliage and Bloom

Postulated	Forecasted[1]				Actual[2]		
PP date[3]	Interval PP-Pk days	Pk date[3]	Interval PP-Ca days	Ca date[3]	Year	Interval PP-Pk, or Pk date, days deviation from forecasted	Interval PP-Ca, or Ca date, days deviation from forecasted
4/21	9	4/30	27	5/18			
4/22	9	5/1	27	5/19			
4/23	9	5/2	27	5/20			
4/24	9	5/3	26	5/20	1945	+2	+4
4/25	9	5/4	26	5/21			
4/26	9	5/5	26	5/22			
4/27	9	5/6	25	5/22			
4/28	9	5/7	25	5/23			
4/29	9	5/8	25	5/24			
4/30	9	5/9	24	5/24			
5/1	8	5/9	24	5/25			
5/2	8	5/10	23	5/25	1941	0	–2
					1942	–1	–4
5/3	8	5/11	23	5/26			
5/4	8	5/12	23	5/27	1938	–1	+3
5/5	8	5/13	22	5/27	1931	+2	+1
5/6	8	5/14	22	5/28			
5/7	8	5/15	22	5/29			
5/8	8	5/16	21	5/29			
5/9	8	5/17	21	5/30	1936	–1	0
					1944	–2	–1
5/10	8	5/18	21	5/31	1932	–3	–2
					1934	0	0
					1937	–1	0
5/11	8	5/19	20	5/31			
5/12	8	5/20	20	6/1	1933	–1	–3
5/13	8	5/21	19	6/1			
5/14	8	5/22	19	6/2	1935	0	+1
5/15	7	5/22	19	6/3	1943	0	–2
5/16	7	5/23	18	6/3	1939	+3	+3
					1940	+3	+2
5/17	7	5/24	18	6/4			
5/18	7	5/25	18	6/5			
5/19	7	5/26	17	6/5			
5/20	7	5/27	17	6/6			

[1] Dates for 1931-1945 were used to determine correlations and these were used in part to get regression equations from which lines were plotted to give the forecasted dates and intervals.
[2] Deviations for each year are located in this table according to the prepink date of that year.
[3] Prepink—when largest leaf blades are as large as a dime; Pink—one day before first opening of any blossoms; Calyx—when about 90 per cent of the petals have fallen.

TABLE 10

Relation of Pink Date to Later Development of Foliage and Bloom

Postulated	Forecasted[1]		Actual[2]	
Pk date[3]	Interval Pk-Ca days	Ca date[3]	Year	Interval Pk-Ca, and Ca date, days deviation from forecasted
5/1	18	5/19		
5/2	17	5/19		
5/3	17	5/20		
5/4	17	5/21		
5/5	17	5/22	1945	+2
5/6	16	5/22		
5/7	16	5/23		
5/8	16	5/24		
5/9	15	5/24	1942	–3
5/10	15	5/25	1941	–2
5/11	15	5/26	1938	+4
5/12	14	5/26		
5/13	14	5/27		
5/14	14	5/28		
5/15	14	5/29	1931	–1
			1932	0
			1944	0
5/16	13	5/29	1936	+1
5/17	13	5/30	1937	+1
5/18	13	5/31	1934	0
5/19	12	5/31	1933	–2
5/20	12	6/1		
5/21	12	6/2		
5/22	11	6/2	1935	+1
			1943	–1
5/23	11	6/3		
5/24	11	6/4		
5/25	11	6/5		
5/26	10	6/5	1939	+1
			1940	0
5/27	10	6/6		
5/28	10	6/7		
5/29	9	6/7		
5/30	9	6/8		
5/31	9	6/9		

[1] Dates for 1931-1945 were used to determine correlations and these were used in part to get regression equations from which lines were plotted to give the forecasted dates and intervals.
[2] Deviations for each year are located in this table according to the pink date of that year.
[3] Pink—one day before first opening of any blossoms; Calyx—when about 90 per cent of the petals have fallen.

off, based on forecasting from the prepink date and the regression equation. In 87 per cent of the years, the calyx date was no more than two days off based on forecasting from the pink date and the regression equation.

The practical use of Table 9 may be explained as follows. If the prepink date is May 9, the pink date could be expected to be May 17 and the calyx date May 30. Actually, in 1946 with the prepink occurring May 9, the pink occurred May 18, and the calyx June 3. Again, if the prepink is May 15, the pink could be expected May 22 and the calyx June 3. In fact in 1947 with the prepink May 15, the pink occurred May 22 and the calyx June 4.

The practical use of Table 10 may be explained as follows. If the pink date is May 18, the expected calyx date would be May 31. In 1946 the two dates were May 18 and June 3. If the pink date is May 22, the expected calyx date would be June 2. In 1947 the two dates were May 22 and June 4.

Any grower who keeps careful records might be able to construct similar tables without the use of mathematical formulae.

Since an examination of the records showed that leaf scab would probably have been reduced in some years by a midbloom application of sulphur, and this is more likely with a longer pink-calyx interval, the forecasting of a longer pink-calyx interval should permit and induce planning for an extra (midbloom) application. Since the records also indicated that leaf scab would probably have been reduced in some years by shorter intervals between the cover applications, and since with an earlier calyx date there would be either longer intervals or more cover applications, the forecasting of an earlier calyx date should permit and induce planning for extra cover applications.

CORRELATION BETWEEN ORIGINAL TRUNK GIRTH, 1939 TRUNK GIRTH, AND ACCUMULATED YIELD RATE THROUGH 1939

In other McIntosh orchards on Highmoor Farm, highly significant coefficients were found for correlation between the 1925 diameter at time of setting and the diameter in later years including 1936, r being +.462 in 1936 (*1*). In the orchard with which this bulletin is chiefly concerned, correlation was studied between the original trunk girth in the spring of 1928, the trunk girth at the end of the 1939 growing season, and the accumulated yield rate through 1939. This was done in the 65 to 74 trees under each fungicidal treatment, and also, for comparison, in the 117 trees from nursery stock of type W, in the 75 trees from nursery stock of type Ff, in the 93 trees in soil type 71B (Sutton, with intermediate slope), and in the 85 trees in soil type 48C (Charlton, with intermediate slope). Nursery type W was seedlings of commercial varieties from the State of Washington, and type Ff was "imported" stock, French crab seedlings grown in France; both were budded with McIntosh in the fall of 1926, grown in a nursery in 1927, and set out in 1928 as "one-year-old" whips.

The relationship of the original trunk girth to trunk girth in subsequent years through 1939 is shown in Fig. 6 for the trees under sulphur dust. The class with an original girth of 1.6 cm. finally surpassed 3

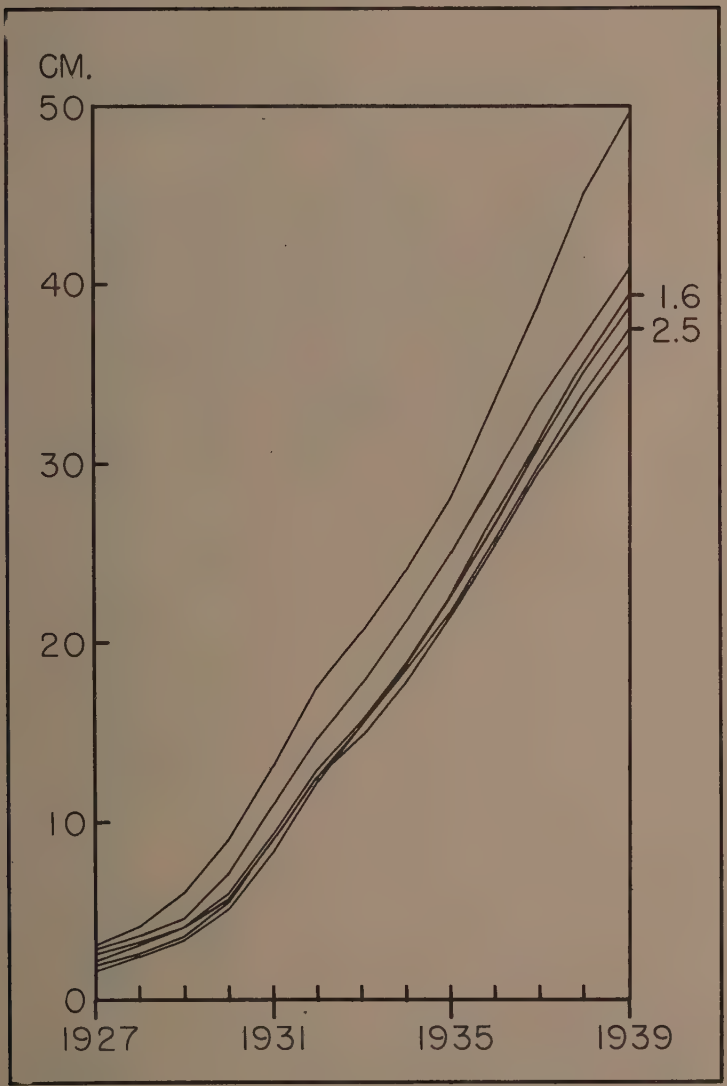

FIGURE 6. Growth for 12 years of trees under sulphur dust; 6, 10, 22, 16, 9, and 2 trees respectively with original trunk girth of 1.6, 1.9, 2.2, 2.5, 2.8, and 3.1 cm. Two numbers at right show final girth of classes with 1.6 and 2.5 cm. girth originally.

classes that started with larger girths, while the class with an original girth of 2.5 cm. (1 inch) fell below two classes that started with smaller

girths. This change is shown in a different way in Fig. 7, where comparisons of different series of trees are made with respect to original trunk girth, final girth, and accumulated yield rate, based on the data in Table 11. Correlation coefficients are given in Table 12, and are all positive. Correlation was highly significant in all classes between trunk

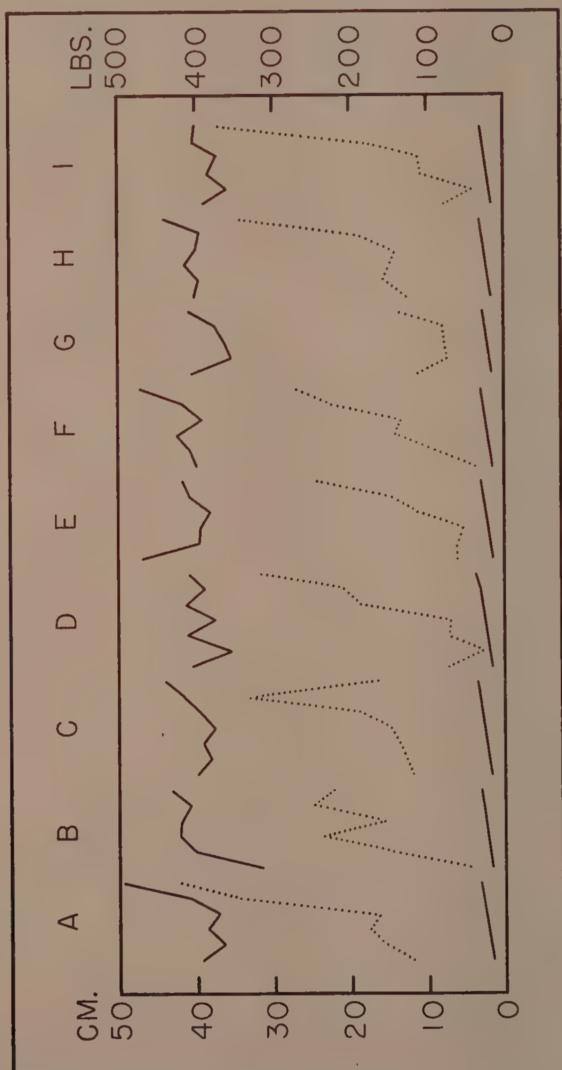

FIGURE 7. Below, original girth; above, girth at end of growing season of 1939; broken line in middle, yield rate per tree for all years together through 1939. Graph for data in Table 11. Letters at top refer to series in Tables 11 and 12.

TABLE 11

Original Trunk Girth and Subsequent Trunk Girth and Fruit Yield

Series	Common characteristic of series	Subseries			
		Original trunk girth[1]	No. of trees	Av. trunk girth end of 1939	Yield per tree through 1939
		cm		cm	lbs.
A	Elemental sulphur dust	1.6	6	39.3	119.7
		1.9	10	36.5	153.6
		2.2	22	38.6	172.7
		2.5	16	37.3	161.6
		2.8	9	40.7	342.9
		3.1	2	49.5	420.0
B	Elemental sulphur spray	1.6	4	31.5	46.5
		1.9	17	40.1	146.0
		2.2	11	42.3	237.1
		2.5	15	42.0	159.4
		2.8	15	40.8	243.9
		3.1	3	43.3	223.7
C	Lead arsenate spray	1.6	5	39.8	119.8
		1.9	10	38.3	128.5
		2.2	19	39.2	136.0
		2.5	24	37.8	147.5
		2.8	11	39.5	184.5
		3.1	4	41.5	334.0
		3.5	1	44.0	165.0
D	Dry lime sulphur spray	1.6	4	40.5	73.5
		1.9	9	35.6	30.7
		2.2	19	41.1	72.1
		2.5	19	37.9	72.9
		2.8	14	41.3	186.4
		3.1	1	39.0	209.0
		3.8	1	41.0	317.0
E	Dry lime sulphur spray[2]	1.6	1	47.0	61.0
		1.9	10	39.7	62.6
		2.2	20	39.5	55.5
		2.5	17	38.4	116.1
		2.8	11	40.8	149.1
		3.1	6	41.8	241.0
F	Nursery stock of type W	1.6	3	40.0	36.0
		1.9	10	40.8	86.8
		2.2	44	42.4	138.9
		2.5	36	39.4	133.3
		2.8	21	41.7	224.0
		3.1	3	47.3	272.3
G	Nursery stock of type Ff	1.6	6	40.5	111.3
		1.9	20	35.5	74.2
		2.2	24	36.3	78.8
		2.5	19	37.3	81.1
		2.8	6	41.0	135.0
H	Soil of type 71B	1.6	7	40.3	125.1
		1.9	24	39.7	156.2
		2.2	23	41.2	152.7
		2.5	22	40.0	141.3
		2.8	14	39.7	189.6
		3.1	3	44.0	340.8
I	Soil of type 48C	1.6	7	38.9	78.6
		1.9	12	35.9	41.9
		2.2	38	38.4	106.9
		2.5	17	37.2	112.2
		2.8	10	40.3	172.0
		3.1	1	40.0	372.0

[1] When set out in the spring of 1928 as "one-year-old" whips, following budding in the fall of 1926.
[2] 1936-39, following lead arsenate spray 1929-35.

TABLE 12

Correlation Between Original Trunk Girth and Subsequent Trunk Girth and Fruit Yield

Series	Characteristic of series	No. of trees	OG (original trunk girth) average	SG (trunk girth end of 1939) average	SY (fruit yield through 1939) average	Correlation coefficient (r)		
						OG vs. SG	OG vs. SY	SG vs. SY
			cm	cm	lbs.			
A	Elemental sulphur dust	65	2.28	38.65	193.3	+.137	+.388[1]	+.680[1]
B	Elemental sulphur spray	65	2.33	40.69	184.6	+.256[2]	+.277[2]	+.587[1]
C	Lead arsenate spray	74	2.37	38.89	155.9	+.058	+.295[2]	+.629[1]
D	Dry lime sulphur spray	67	2.37	39.51	96.4	+.096	+.503[1]	+.585[1]
E	Dry lime sulphur spray[3]	65	2.41	39.80	107.2	+.038	+.421[1]	+.562[1]
F	Nursery stock of type W	117	2.38	41.30	148.8	+.018	+.324[1]	+.511[1]
G	Nursery stock of type Ff	75	2.20	37.03	85.3	+.070	+.054	+.670[1]
H	Soil of type 71B	93	2.27	40.30	160.4	+.040	+.181	+.331[1]
I	Soil of type 48C	85	2.25	37.93	107.2	+.055	+.320[1]	+.533[1]

[1] Highly significant r (*12*, Table 7.3).
[2] Significant r (*12*, Table 7.3).
[3] 1936-39, following lead arsenate spray 1929-35.

girth at the end of 1939 and accumulated yield through 1939. Correlation was somewhat lower but still generally highly significant between original girth and accumulated yield, while correlation was usually low between original girth and final girth. No consistent differences are apparent as between the series under the different fungicidal treatments. It may be concluded that, under the described conditions, greater girth at setting gave some indication of the final girth to be expected and gave considerable indication of the yield rate over a period of years, while final girth was closely linked with accumulated yield over the same period.

COMPARISON WITH RESULTS OBTAINED ELSEWHERE

Several publications covering tests like some of those described in this bulletin, should be reviewed.

In Virginia, Groves (*7*) compared liquid lime sulphur 1-50 with flotation sulphur paste 6-50 on Starking Delicious 1942-45 inclusive and found with the paste an average annual difference per tree of 1.79 bushels or 44 per cent over the yield rate under the lime sulphur. Girth increase in 5 years was only 0.32 inches or 3 per cent greater under flotation sulphur than under lime sulphur, the difference not being statistically significant. In 1943 the lime-sulphur trees had much fewer blossoms. He attributes the lack of effect on growth to the fact that "the different treatments did not cover the major growth period but extended into the earlier part of the growing season after which treatments became uni-

form." However, in Maine the different treatments were continued through July; monthly measurements in 1932 showed that two thirds of the growth took place by July 31 and most of the growth ended by August 22 (*4*, p. 466-469). In his review of previous literature, Groves brings out that other investigators have found lime sulphur, in comparison with elemental sulphur, to reduce yield rate, leaf efficiency in making carbohydrates, and amount of starch stored in the wood.

In New York, Mills (*10*) compared rows of McIntosh trees receiving flotation sulphur spray with rows receiving liquid lime sulphur spray 1933-37, both treatments controlling scab very well. The flotation sulphur increased leaf size, decreased fruit drop, decreased fruit size, and increased annual yield per tree by several bushels, as compared with the lime sulphur. His extensive review of previous literature shows that other investigators in various instances have found, under elemental sulphur in comparison with lime sulphur, more bloom, less fruit drop, smaller fruit size, and greater leaf size. His own work also indicated that several types of elemental sulphur were similar in their beneficial effects, and that following lime sulphur it might take more than one season to reach the full benefits of elemental sulphur.

In Michigan, Rasmussen *et al.* (*11*) found the yield rate per tree per year 1940-44 inclusive to be increased by wettable sulphur in comparison with liquid lime sulphur, to the extent of 2.4 and 2.0 bushels in Northern Spy and Delicious, respectively. Corresponding increases for 1942-44 inclusive were 3.6, 2.3, 1.8, and 3.2 bushels in McIntosh, Jonathan, Northern Spy, and Rhode Island Greening respectively. These increases, in percentage, ran from 12 to 32 per cent.

The results from tests made elsewhere, as given in the reports and literature reviews covered above, confirm many of the results of the Maine comparisons of sulphur fungicides covered by this bulletin, although the comparative effects of sulphur fungicides may vary somewhat from one region, one variety, or one year to another.

DISCUSSION

The use of a fungicide on apple trees should not be regarded as a simple matter involving only the cost of the fungicide and its effectiveness against one or more diseases. It affects a complicated situation. Within a given apple variety, the rate of tree growth is subject to environmental and cultural factors such as soil, weather, insects, fungi, pruning, fertilizing, mulching, and pollination. McIntosh apple trees, while producing wood fairly steadily year after year and generally increasing their fruit yield to correspond, often build up yield rate un-

evenly and produce somewhat less wood in the "on" years for fruit yield. A fungicide by controlling leaf scab, or by reducing the physiological efficiency of the leaves, may affect early summer fruit drop, fruit yield, and wood growth, and the effects may not be all apparent during the first season of application of the fungicide. Consequently many measurements should be made and studied over a period of years, before the full effects of any one fungicide are assumed to be known.

In considering only the effects of a fungicide upon scab, it is important that the disease be studied on both the leaves and the fruits. Good control of fruit scab may occur in spite of rather poor control of leaf scab. In such a case the value of the fungicide may prove uncertain as to yield rate in bad leaf scab years, and considerable leaf scab may not justify giving up control measures for the season.

It may be pointed out that the forecasting values of early tree stage dates may well be greater in Maine than farther west where south winds in spring are less tempered by the ocean and where northwest storms have not been toned down by passage across the country.

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